

United States Military Academy
West Point, New York 10996

**Initial Set of Use Cases for High-Fidelity
Synthetic Environment / Virtual Autonomous
Navigation Environment Development Tied to
Unmanned Ground Vehicle Capability Gaps**

OPERATIONS RESEARCH CENTER OF EXCELLENCE
TECHNICAL REPORT #DSE-TR-0912
DTIC #: ADA486602

Joyce A. Nagle, Ph.D.

Research Engineer, U.S. Army Engineer Research and Development Center Cold
Regions Research and Engineering Center, Hanover, NH

Niki C. Goerger, Ph.D.

Liaison for the U.S. Army Engineer Research and Development Center
to the U.S. Military Academy, Department of Systems Engineering

Lieutenant Colonel Suzanne M. DeLong, M.S.

Assistant Director, Operations Research Center of Excellence

Approved by

Colonel Timothy E. Trainor, Ph.D.

Professor and Head, Department of Systems Engineering

SEPTEMBER 2008

Distribution A: Approved for public release; distribution is unlimited.

**Initial Set of Use Cases for High-Fidelity Synthetic
Environment / Virtual Autonomous Navigation
Environment Development Tied to Unmanned Ground
Vehicle Capability Gaps**

Joyce A. Nagle, Ph.D.

Research Engineer, U.S. Army Engineer Research and Development Center, Vicksburg, MS

Niki C. Goerger, Ph.D.

Research Engineer, U.S. Army Engineer Research and Development Center, Vicksburg, MS

Lieutenant Colonel Suzanne M. DeLong, M.S.

Assistant Director, Operations Research Center of Excellence, West Point, NY

**OPERATIONS RESEARCH CENTER OF EXCELLENCE
TECHNICAL REPORT #DSE-TR-0912
DTIC #: ADA486602**

Approved by

Colonel Timothy E. Trainor, Ph.D.

Professor and Head, Department of Systems Engineering

SEPTEMBER 2008

The Operations Research Center of Excellence is supported by the Assistant Secretary of the Army
(Financial Management & Comptroller)

This Research was sponsored by Office of the Undersecretary of Defense for Acquisition, Technology &
Logistics/Portfolio Systems Acquisition, Land Warfare & Munitions
Joint Ground Robotics Enterprise

Distribution A: Approved for public release; distribution is unlimited.

Abstract

To help guide alternative assessments and experiments for the development of a high-fidelity synthetic environment (HFSE), an initial set of Use Cases was developed based on Capability Gaps identified in the U.S. Army/U.S. Marine Corps Ground Robotics Master Plan (Robotics Systems Joint Project Office (RS JPO), 2007). Four specific scenarios were developed in which an unmanned ground vehicle (UGV) is employed to contribute to a mission. The Use Cases are narrative descriptions of a sequence of actions a Warfighter equipped with a UGV, would undertake to accomplish a goal. The Use Cases do not identify requirements, but rather imply them in the stories they tell, leaving it up to an analyst to identify the requirements. The Use Cases avoid identifying or describing specific platforms, but rather create opportunities for analysts to identify capabilities. The Use Cases developed will provide the structure in which we can analyze both the HFSE and the UGV performance in the HFSE.

About the Authors

Joyce A. Nagle is a research engineer with the U.S. Army Engineer Research and Development Center (ERDC). She works in the area of battlespace environments and mobility. She received her BS in Botany and MSE degrees in Water Resources and Environmental Engineering from the University of Michigan and her Ph.D. in Engineering Sciences from Dartmouth College.

Niki C. Goerger is a research engineer with the U.S. Army Engineer Research and Development Center (ERDC). Her expertise is in the area of physics-based and effects-based representation and quantitative analysis in modeling and simulation (M&S) for military applications. She is currently a research associate at the United States Military Academy with research tracks in analysis for countering improvised explosive devices, M&S and Battle Command interoperability, and physics-based representation in simulations. She received her BS in Biological Engineering and MS in Agricultural Engineering from Mississippi State University and her Ph.D. in Industrial Engineering from Texas A&M University.

Lieutenant Colonel (LTC) Suzanne DeLong graduated from the United States Military Academy in 1990 and was commissioned a Second Lieutenant, serving as an Air Defense Artillery Officer and commanded at the Platoon and Battery level in the HAWK and PATRIOT Weapon Systems. Military assignments include Germany, Ft. Bliss, TX and Ft. Hood, TX and a deployment to Saudi Arabia. LTC DeLong is now an Army Operations Research Systems Analyst who earned a Masters Degree and is currently completing her PhD from The University of Virginia. LTC DeLong is on her second tour as an Assistant

Professor in the Department of Systems Engineering at USMA and is currently the Deputy Director for the Operations Research Center.

Acknowledgements

This report was prepared as a deliverable to the Office of the Secretary for Defense Joint Ground Robotics Enterprise (JGRE). The work was sponsored by JGRE through the Robotic System Joint Project Office (RS JPO) and leveraged a portion of the Army 6.2 Research, Development, Test and Evaluation (RDT&E) program conducted through the U.S. Army Engineer Research and Development Center (ERDC).

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products. All product names and trademarks cited are the property of their respective owners. The findings of this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Table of Contents

Abstract	iii
About the Authors	iv
Acknowledgements	vi
Table of Contents	vii
List of Figures	viii
List of Tables	viii
Chapter 1: Introduction.....	1
Chapter 2: Project Overview	3
Chapter 3: Use Case Development	5
Chapter 4: Use Case Descriptions	9
4.1 Overview	9
4.1.1. Use Case #1: Locate Possible Enemy Improvised Firing Point/Device.....	11
4.1.2. Use Case #2: Provide Surveillance for Perimeter Security of a Local Municipal Water Supply	15
4.1.3. Use Case #3: Respond to CBRN Attack.....	17
4.1.4. Use Case #4: Reconnaissance and Surveillance of a Building	18
Chapter 5: Summary	19
Chapter 6: Future Work.....	19
References	21
Appendix A: Acronyms	22
Distribution List	24
Chapter 7: REPORT DOCUMENTATION PAGE – SF298	26

List of Figures

Figure 1. Tasks and products for the high-fidelity synthetic environment (HFSE)	
requirements and design analysis.....	4
Figure 2. Process for deriving Use Cases from the Capability Gaps identified in the Ground	
Robotics Master Plan (GRMP).	6

List of Tables

Table 1. Use Case description format.	11
Table 2. Force Operating Capabilities (FOC) Capability Gap Statements identifying	
maneuver, search, detect, and locate.....	12
Table 3. Use Case for locating a possible enemy improvised firing point/device.....	14
Table 4. Force Operating Capabilities (FOC) Capability Gap Statements identifying	
providing surveillance.....	15
Table 5. Use Case for providing surveillance at a local municipal water supply.	16
Table 6. Force Operating Capabilities (FOC) Capability Gap Statements identifying detect	
CBRN and toxic industrial agent/hazard releases.....	17
Table 7. Use Case for responding to a CBRN attack.....	17
Table 8. Use Case for providing reconnaissance and surveillance of a building.	18

Chapter 1: Introduction

The Office of the Secretary of Defense (OSD) Joint Ground Robotics Enterprise (JGRE) oversees the consolidation of robotic efforts across the Department of Defense (DoD), establishes robotics operational capabilities, and pursues needed critical technologies to meet these capabilities in the area of ground robotics (Joint Ground Robotics Enterprise, 2006). One stated critical technology area involves supporting the development of vehicle onboard intelligence and tactical behaviors to enable fielding of autonomous unmanned systems. As unmanned ground vehicle (UGV) platforms are developed and assessed throughout the acquisition lifecycle, environments for development and assessment of systems and subsystems are often rebuilt. This results in duplication of effort, increased costs, and limited ability to compare or pool results. This becomes even more problematic with the assessment of UGV navigation performance as it is sensitive to the content (features and attributes) and resolution of the environment.

The vision of the JGRE is to support the development and fielding of a family of affordable and effective mobile ground robotic systems; develop and transition technologies necessary to meet evolving user requirements; and serve as a catalyst for insertion of robotic systems and technologies into the force structure. To advance these goals, a need has been identified to develop a high-fidelity synthetic environment (HFSE) to facilitate design and assessment of UGV performance, particularly in the areas of mobility, obstacle and target detection, and navigation.

The HFSE is meant to support development of UGVs, including engineering- and operational- level capabilities. Engineering-level capabilities consist of such things as

development of sensor platforms on UGVs, perception and sense-making algorithms for UGVs, and mobility. Operational-level capabilities include assessment of UGV contributions as supporting efforts to missions.

As part of the effort, we identified stakeholders, determined needs and required system functions, and developed an integrated decision framework by which to assess the HFSE design options. The decision framework links functionality parameters, value models, and metrics to generate and assess design alternatives for an HFSE. This work is being sponsored by the JGRE through the Robotic Systems Joint Project Office (RS JPO) and leverages the U.S. Army 6.2 Research, Development, Test and Evaluation program being conducted through the U.S. Army Engineer Research and Development Center (ERDC).

To help guide alternative assessments and experiments for the development of an HFSE, an initial set of Use Cases was developed based on Capability Gaps identified in the U.S. Army/U.S. Marine Corps Ground Robotics Master Plan (GRMP) (Robotics Systems Joint Project Office (RS JPO), 2007). The GRMP was developed in response to senior leadership's direction to provide an effective means of assessing criticality of ground robotic Science and Technology (S&T) Projects to Current and Future Capability Gaps and S&T Shortfalls, and to identify linkages to Acquisition/Contingency Programs.

In this work, a Use Case is a specific scenario, or vignette, in which a UGV is employed to contribute to a mission. It is a narrative description of a sequence of actions a Warfighter equipped with a UGV, would undertake to accomplish a goal. The Use Cases do not identify requirements, but rather imply them in the stories they tell, leaving it up to an analyst to identify the requirements. The Use Cases avoid identifying or describing specific platforms, but rather

create opportunities for analysts to identify capabilities. The capability requirements we derived in this manner provided a valuable supplement to UGV capability gaps assessments.

Chapter 2: Project Overview

Figure 1 depicts the approach and outcomes, or products, for the HFSE requirements and design analysis conducted in FY07 and FY08. The approach involved conducting a stakeholder analysis, developing a value hierarchy and model, generating and assessing the HFSE design options using the value model, and conducting experiments to demonstrate the HFSE potential and proof of concept. The stakeholder analysis gathered information on issues and the needs of stakeholders. Thus, as a foundational part of the development of the HFSE, a literature review was conducted and a series of interviews and collaborative sessions with stakeholders were used to elicit information pertinent to its functionality. This led to the generation of a framework for assessing the HFSE architecture and design that mapped needed HFSE functions to value measures. Value modeling provided information for evaluating candidate solutions. Given the value model, it is possible to use value-focused thinking in considering alternatives for the HFSE architecture. Use Case development provides a focus for scoping assessments and supports experiments that develop the HFSE within the stakeholder community.

Experiment 2 is a two-fold experimentation process. First, an experimental test bed is created and evaluated based on the stakeholder analysis completed and incorporates the stakeholders needs, wants and desires with respect to the HFSE. There are several recommendations from the stakeholder analysis to take into consideration during the development of the UGV experimental test bed and helped guide the development of the UGV HFSE test bed.

Second, the UGV experimental test bed is used to evaluate the Use Case for the experiment in order to demonstrate the capabilities of the test bed with respect to the actual performance of the UGV given the Use Case in the HFSE. For Experiment 2, Use Case #1, maneuver, search, detect and locate, is utilized to demonstrate some basic UGV functionality within the test bed as well as to develop UGV performance metrics for the purpose of assessing the UGV within the test bed given the Use Case #1 scenario.

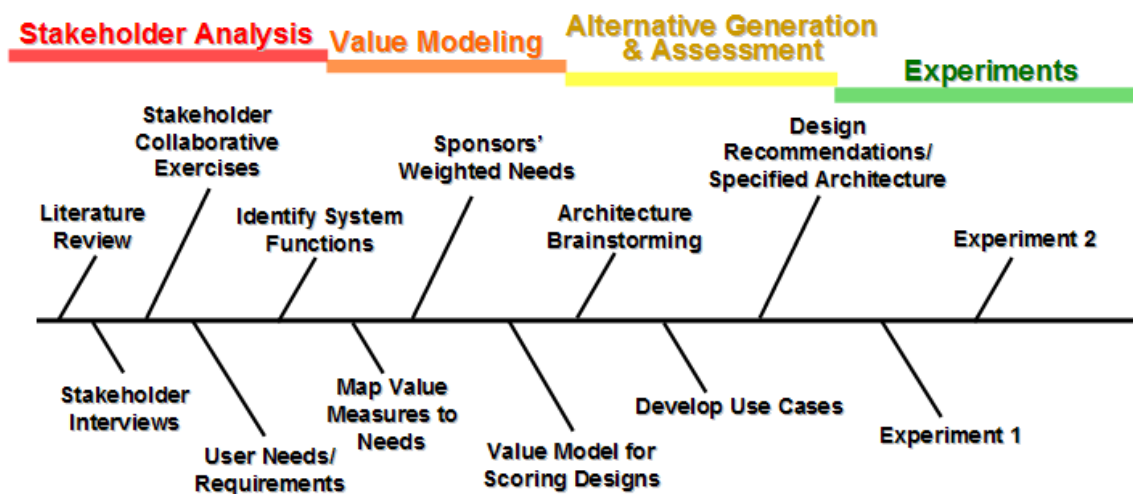


Figure 1. Tasks and products for the high-fidelity synthetic environment (HFSE) requirements and design analysis.

The constraints, limitations, and assumptions for the analysis were as follows:

- The analysis was constrained to UGVs;
- Both current and future acquisition and contingency programs were considered. Autonomous, semi-autonomous, and teleoperated systems were within the scope of the analysis;
- The focus was constrained to the earlier stages of the acquisition lifecycle through fielding (e.g., concept exploration; research and development; and engineering);

- Both virtual and constructive environments were included;
- The limitations of this analysis included lack of stated UGV requirements and uncertainty regarding how UGVs will be employed; and
- An assumption was made that the input gathered reflected that of the broader stakeholder community.

Chapter 3: Use Case Development

The intent of developing Use Cases was two-fold. First, to provide a guide, or scope of sorts, regarding issues to explore that would be better served by involving high-fidelity synthetic environments and, secondly, to support experiments that enable the proof of principle and development of the HFSE with the stakeholder community. The intent is not to impinge on the U.S. Army Training and Doctrine Command (TRADOC) mission and, as such, these Use Cases are not intended to be certified or authoritative in that sense. They are meant to support our development efforts and to generate discussion.

It is important to note that these Use Cases were not developed in a vacuum but were informed by the literature, findings of the stakeholder analysis, and discussions with and products from subject matter experts. The principal document used in developing the Use Cases was the U.S. Army/U.S. Marine Corps Ground Robotics Master Plan (GRMP) (RS JPO, 2007). Additionally, the RS JPO, the Maneuver Support Center (MANSCEN), and other stakeholders provided discussions and Use Cases under development in conjunction with their programs. The stakeholder analysis captured a broad scope of the types of issues the community needed to investigate and related the needs for the HFSE functionality (Goerger et al., 2008).

The GRMP responds to direction from U.S. Army Program Executive Office Ground Command Systems (PEO-GCS), Commanding General (CG) U.S. Army Research, Development, and Engineering Command (RDECOM), and CG, U.S. Marine Corps Systems Command (MARCORSYSCOM). It is intended to provide Army and Marine Corps ground robotic stakeholders a common information resource document, as well as a comprehensive plan that links robotic Science and Technology (S&T) Projects and Acquisition/Contingency Programs to User Current Capability Gaps, Future Capability Gaps, and S&T Shortfalls. The GRMP summarizes the UGV Capability Gaps identified by the maneuver, maneuver support, and combat service support communities as supporting the TRADOC Force Operating Capabilities (FOC).

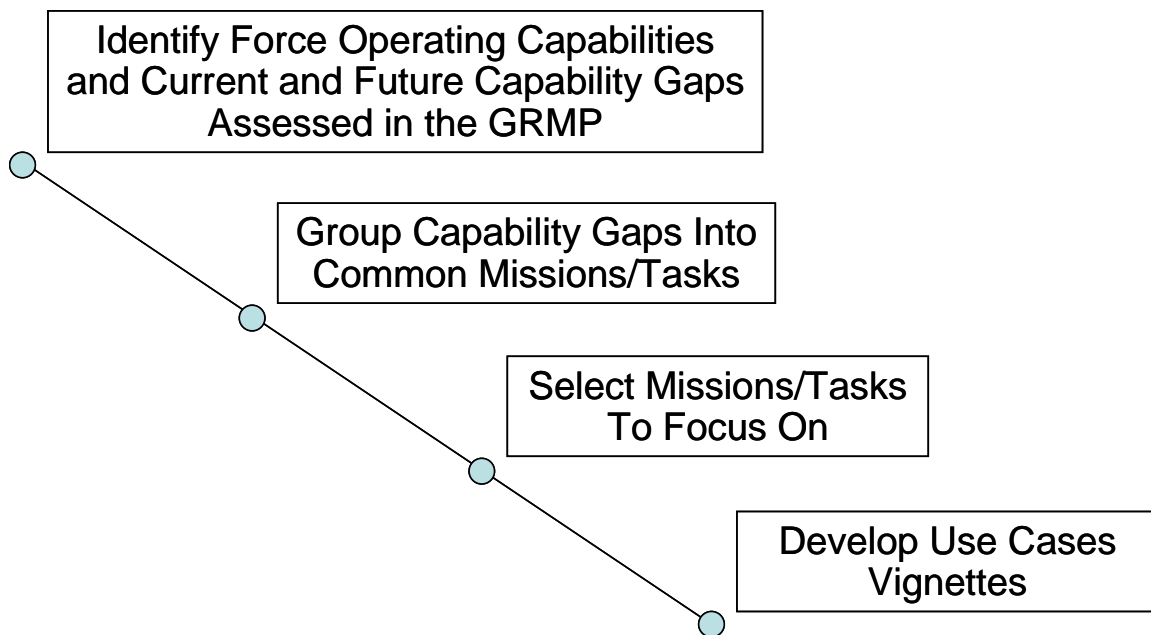


Figure 2. Process for deriving Use Cases from the Capability Gaps identified in the Ground Robotics Master Plan (GRMP).

The process used to develop the Use Cases described in this report is shown in Figure 2. As a first step, all of the User FOC and Capability Gap data submitted to the GRMP were

assessed to identify the various tasks supported by the Army Tactical Tasks (ART) (Headquarters, Department of Army, 2007) and Marine Corps Tasks (MCT) (Headquarters, Department of Navy, 2007). Next, the Capability Gaps were put into groupings based on common missions and ART and MCT.

Three criteria were used to decide on which mission/tasks to focus Use Case development:

1. Which missions or tasks were most frequently related to the GRMP Capability Gaps?
2. How would the development of a HFSE help overcome a Capability Gap? and
3. How many Army and Marine Corps ground robotic Acquisition/Contingency Programs and S&T Projects are affected by the Capability Gap?

For example, in the GRMP, providing a UGV with the capability to maneuver, search, detect, and locate objects such as an improvised explosive device (IED), target, or mine, in autonomous or semi-autonomous mode in day, night, and all-weather conditions was cited in 10 out of 38 Capability Gaps. The maneuver, search, detect, and locate ART and MCT are applicable to several robotic platforms. Moreover, a HFSE would enhance the ability to achieve these capabilities in various conditions and environments.

Using the above criteria three areas were selected for Use Case vignette development:

1. Maneuver, search, detect, and locate;
2. Detect chemical, biological, radioactive, and nuclear (CBRN) and toxic/industrial agent/hazard; and
3. Provide surveillance.

Some examples of Capability Gaps associated with each of the selected focus areas are shown below. The numbers associated with each Capability Gap corresponds to the Capability Gap Statements paragraphs in Appendix D of the GRMP (RS JPO, 2007).

1. Maneuver, search, detect, and locate

- “Provide autonomous UGV capable of maneuvering, searching, detecting and locating improvised explosive device (IED) threats.” (RS JPO, 2007 Appendix D - Capability Gap Statement 2.6.3.1)
- “Provide Unmanned Systems (UMS) with an all-weather, all-terrain day/night ability to maneuver, search, detect, provide reconnaissance and locate targets.” (RS JPO, 2007 Appendix D - Capability Gap Statement 2.9.3)
- “Provide UGV with autonomous ability to maneuver, search, detect, and locate and designate targets in a specified area, day/night ability of UGV to provide real-time location and imagery data to lowest echelon.” (RS JPO, 2007 Appendix D - Capability Gap Statement 2.10.1)

2. Detect chemical, biological, radioactive, and nuclear (CBRN) and toxic/industrial agent/hazard

- “Ability to detect and warn Soldiers of CBRN and toxic industrial agent/hazards releases...” (RS JPO, 2007 Appendix D - Capability Gap Statement 3.7.1)

3. Provide surveillance

- “Provide 360-degree surveillance and detection of ground approaches to ammunition caches.” (RS JPO, 2007 Appendix D - Capability Gap Statement 5.6.3.1)
- “Provide intruder alert to a Quick Reaction Force location.” (RS JPO, 2007 Appendix D - Capability Gap Statement 5.6.3.2)

Finally, specific scenarios, or vignettes, were developed for each of the focus areas. These Use Cases were based on examination of existing Use Cases developed by stakeholders, further review of literature, and discussions with the sponsor of this work. The purpose is not to completely specify the Use Case for instantiation in a particular simulation but is to provide enough detail to enable that development. For example, the type of robotic platform and specific sensors are not prescribed. The Use Cases do not identify requirements, but rather imply them in the stories they tell, leaving it up to an analyst to identify the requirements. The Use Cases avoid identifying or describing specific platforms, but rather create opportunities for analysts to identify capabilities. The capability requirements we derived in this manner provided a valuable supplement to UGV Capability Gaps assessments.

Chapter 4: Use Case Descriptions

4.1 Overview

Use Cases were developed in the most general terms. This was meant to broaden the spectrum of considered capabilities and technology enablers for UGVs. The Use Cases were intended to be generic with no focus on a particular foreign country or group of people. The Use Case timeframe is applicable for Current and Future Forces through 2032 as identified by the

Office of the Secretary of Defense's Unmanned Systems Roadmap 2007-2032 (Office of Secretary of Defense, 2007).

Four initial Use Cases were developed and are discussed in the following sections.

- Use Case #1 – Locate possible enemy improvised firing point/device;
- Use Case #2 – Provide surveillance for perimeter security of a local municipal water supply;
- Use Case #3 – Respond to chemical, biological, radiological, and nuclear (CBRN) attack; and
- Use Case #4 – Conduct reconnaissance and surveillance of a building.

Maneuver underlies most of the Use Case tasks. It does not necessarily underlie surveillance in the case of fixed assets. Detect and locate tasks are generally associated with assisting in target engagement (Headquarters, Department of Army, 2007) but are also associated with detection of contaminants. Reconnaissance and surveillance are conducted to support intelligence production and decision making (Headquarters, Department of the Army, 2003).

Table 1 describes the format used to document each of the Use Cases in this report. Each Use Case was documented by filling in the columns on the right with the information described by the respective headings on the left. The Use Case was linked to appropriate FOC and Capability Gaps as documented in Appendix D of the GRMP. Each Use Case is linked to the appropriate Army Tactical Tasks (ART) listed in the Army Universal Task List (AUTL) (Headquarters, Department of Army, 2007) and the appropriate Marine Corps Tasks (MCT) listed in the Marine Corps Task List (MCTL) (Headquarters, Department of Navy, 2007).

Table 1. Use Case description format.

Use Case Title	
Name Description	Descriptive title of the Use Case
Situation	Summary of the scenario the Use Case describes. The scenario should highlight the need for at least one specific requirement associated with a Capability Gap.
Condition	A variable of the operational environment or situation in which a unit, system, or individual is expected to operate that may affect performance.
Task	A discrete event or action, not specific to a single unit, weapon system, or individual that enables a mission or function to be accomplished. This is the element of the mission containing the “what.”
Purpose	Element of the mission containing the objective for the Use Case which describes the anticipated result which will guide the actions.
Doctrine	Links to the Army Universal Task List (AUTL) (Headquarters, Department of Army, 2007) and the Marine Corps Task List (MCTL) (Headquarters, Department of Navy, 2007).
Notes	Documentation of the requirements for which the Use Case illustrates a need and any issues that might prevent their unambiguous specification.

For each Use Case the list of associated Capability Gaps from the GRMP is given. The number in the Capability Gap Statement column is the number associated with the Capability Gap Statement in Appendix D of the GRMP (for example, see Table 2). This allows the interested reader to refer back to the GRMP when desired.

4.1.1. Use Case #1: Locate Possible Enemy Improvised Firing Point/Device

Counter-IED operations consisting of UGVs employed to identify IED and firing points using the functional threads of maneuver, search detect and locate while conducting route clearing operations. Analysis of the FOC and Capability Gaps listed in Appendix D of the GRMP identified maneuver, search, detect, and locate in 10 of 38 Capability Gaps (Table 2).

Table 2. Force Operating Capabilities (FOC) Capability Gap Statements identifying maneuver, search, detect, and locate.

FOC Area / Specific FOC	FOC Description	Capability Gap Statement
FOC Area: Mounted/Dismounted Maneuver	Tactical maneuver capabilities for precise, decisive maneuver, horizontal and vertical, day, and night in all terrain and weather conditions.	¹ 2.6.3.1 Autonomous ability to maneuver, search, detect, and locate Improvised Explosive Device (IED) threats.
FOC Area: Mounted/Dismounted Maneuver	Autonomously maneuver, search, detect, and locate targets in a specified area.	2.14.3 Autonomous ability to maneuver, search, detect, and locate targets in specified area. Ability to collect and distribute real-time location and imagery data on targets.
FOC Area: Mounted/Dismounted Maneuver	UGV target engagement	2.18.3 Autonomous ability to maneuver, search, detect, locate and designate targets for smart or precision munitions; identify and engage line-of-sight (LOS) targets.
FOC Area: Mounted/Dismounted Maneuver FOC-03-01 Mobility	Future Force units will possess superior tactical mobility. Units must possess superior capability to detect presence, identify disposition, and counter antitank and antipersonnel (AT/AP) mines, above and below surface, and booby traps, such as side-charge and remote detonated mines. Future Forces must have standoff means for detection and defeat of obstacles, the ability to mark or perform in-stride counters to neutralize mines at a distance, and the ability to detect and locate other man-made obstacles.	4.9.3 Detect explosive hazards in time to plan and execute by-pass maneuvers or neutralizing operations.
FOC Area: Mounted/Dismounted Maneuver FOC-03-02 Operations in	Future adversaries will focus on urban areas (or complex terrain) to negate technological overmatches in intelligence and weapon	4.10.3 Detect explosive hazards in an urban environment.

¹ The numbers associated with each Capability Gap Statement correspond to the Capability Gap Statements paragraphs in Appendix D of the GRMP (Robotics Systems Joint Project Office, 2007).

FOC Area / Specific FOC	FOC Description	Capability Gap Statement
Urban and Complex Terrain	systems and as a means of creating strongholds where he can achieve sanctuary from our effects. Such settings degrade weapon system standoff, are troop and supply-intensive, and add complexity to the application of firepower to avoid collateral damage and non-combatant injuries.	
FOC Area: Line of Sight/Beyond Line of Sight (LOS/BLOS), Non-Line of Sight (NLOS) Lethality for Mounted/Dismounted Operations	Ability of small tactical units to locate and designate targets (day or night) with UMS in all terrain.	2.10.3 Autonomous, real-time day/night ability to maneuver, search, detect, locate, and designate targets in a specified area.
FOC Area: Line of Sight/Beyond Line of Sight (LOS/BLOS), Non-Line of Sight (NLOS) Lethality for Mounted/Dismounted Operations	Ability to detect and engage enemy first in Military Operations on Urban Terrain (MOUT).	2.11.3 Autonomous ability to maneuver, search, detect, locate, and engage targets in MOUT.
FOC Area: Line of Sight/Beyond Line of Sight (LOS/BLOS), Non-Line of Sight (NLOS) Lethality for Mounted/Dismounted Operations	Provide squad level lethal NLOS capability in MOUT.	2.13.3 Autonomous ability to maneuver, search, locate, and designate targets for smart or precision munitions.
FOC Area: Maneuver Support FOC-06-01 Provide Assured Mobility	Guarantee the force commander the ability to deploy, move, and maneuver where and when she desires, without interruption or delay, to achieve his intent.	4.8.3 The capability gap is the ability to detect at standoff distances sufficient enough to provide protection to the Soldier and/or platform; the capability to detect explosive hazards, in measures of time and distance, sufficient enough to plan for and execute by-pass maneuvers or, if necessary neutralizing operations.
FOC Area: Protection FOC-07-01 Protect personnel	To provide effective personnel protection, the Future Engineer Force must detect, monitor, track and engage adversary threats	4.7.3 The capability to detect explosive hazards at standoff distances sufficient enough to provide protection to the

FOC Area / Specific FOC	FOC Description	Capability Gap Statement
	directed against military and civilian personnel. Surveillance, detecting and tracking must provide the necessary real-time 360-degree hemispherical data to commanders to view the overall threat to military and civilian personnel. Capabilities must include the ability to sense/detect personnel-borne explosive devices, including a stand-off detection capability.	Soldier and/or platform.

Table 3 describes Use Case #1 which was designed to operate a UGV in a HFSE and perform maneuver, search, detect, and locate tasks. Use Case #1 was built around locating a possible enemy improvised firing point or device. This is an effort that could be performed by autonomous, semi-autonomous or teleoperated UGVs using current and future vehicle platforms.

Table 3. Use Case for locating a possible enemy improvised firing point/device.

Use Case #1: Locate possible enemy improvised firing point/device	
Name Description	Maneuver, search, detect, and locate possible enemy improvised firing point/device.
Situation	Possible enemy improvised firing point/device. Iraq urban terrain; heavy civilian foot and vehicle traffic; enemy direct fire unlikely; daylight hours.
Task	Conduct reconnaissance using UGV.
Purpose	Confirm or deny possible rocket firing point.
Doctrine	ART 2.3 Conduct Intelligence, Surveillance, and Reconnaissance. ART 2.3.3 Conduct Tactical Reconnaissance MCT 2.2 Collect Data and Intelligence MCT 2.2.1 Conduct Tactical Reconnaissance
Notes	Maneuver operations are highly restricted since armored vehicles may damage streets, homes, automobiles, etc. Additionally, streets are often cluttered with day-to-day activities that should not be interrupted with military operations. There is much more background clutter in the form of radio transmissions, lights, pedestrians, civilian automobiles, and other interferences that degrade the performance of military

Use Case #1: Locate possible enemy improvised firing point/device	
	<p>communications, sensors, and human sensing.</p> <p>The probability of Warfighter interacting with civilians is high so there is a much greater requirement for our Warfighter to understand the local populace in terms of language and culture.</p> <p>Combat operations focus principally on a limited, concrete set of effects, such as the number of targets engaged.</p>

4.1.2. Use Case #2: Provide Surveillance for Perimeter Security of a Local Municipal Water Supply

A common task performed by UGV is surveillance. The analysis of the FOC and Capability Gap Statements in the GRMP identified providing surveillance in four instances of 38 as shown in Table 4.

Table 4. Force Operating Capabilities (FOC) Capability Gap Statements identifying providing surveillance.

FOC Area / Specific FOC	FOC Description	Abbreviated Capability Gap Statement
FOC Area: Maneuver Support FOC-06-01 Provide Assured Mobility	Improve the Army's ability to protect Mission Essential Vulnerable Areas (MEVA) by deploying robotic platforms that perform both security and inventory functions at DoD warehouses, storage sites and other facilities. Provide capability to predict, detect, prevent, avoid, neutralize, and protect. Ability to conduct area security and reconnaissance / counter reconnaissance operations and provide force protection and physical security. Detecting, monitoring, tracking and engaging adversary threats directed against military and civilian personnel.	5.6.3.1 360-degree surveillance and detection of ground approaches to ammunition caches.
FOC Area: Maneuver Support FOC-06-01 Provide Assured Mobility		5.6.3.2 Provide intruder alert to a Quick Reaction Force location.
FOC Area: Maneuver		5.6.3.3 24 hours, seven

FOC Area / Specific FOC	FOC Description	Abbreviated Capability Gap Statement
Support FOC-06-01 Provide Assured Mobility		days a week surveillance coverage.
FOC Area: Maneuver Support FOC-06-01 Provide Assured Mobility		5.6.3.4 Protection and surveillance system operational in extreme weather (Iraq, Afghanistan).

Table 5 describes Use Case #2 which was designed for UGV to provide actionable intelligence to a reaction force. We chose to craft the Use Case in terms of stability, security, transition, and reconnaissance operations (SSTRO) and in support of homeland defense type concerns. This scenario could incorporate multiple UGV, unmanned aerial vehicles (UAV), and fixed sensors in autonomous, semi-autonomous, or teleoperated fashion. It is applicable to current and future platforms.

Table 5. Use Case for providing surveillance at a local municipal water supply.

Use Case #2: Provide Surveillance for Perimeter Security of a Local Municipal Water Supply	
Name Description	Provide surveillance for perimeter security of a local municipal water supply.
Situation	Local municipal water supply needs full-time surveillance for protection. MEVA in area with operating insurgents and low police response.
Task	Conduct surveillance using UGV (could be in conjunction with other assets). Notify quick reaction force when necessary to take action.
Purpose	Protection of municipal water supply.
Doctrine	ART 2.3 Conduct Intelligence, Surveillance, and Reconnaissance ART 2.3.4 Conduct Surveillance MCT 2.2 Collect Data and Intelligence MCT 2.2.9 Conduct Reconnaissance and Surveillance
Notes	

4.1.3. Use Case #3: Respond to CBRN Attack

There are several ongoing efforts in UGV navigation and sensing that deal with identifying and mapping contaminants (Nielsen et al., 2008; Bruemmer et al., 2008). While there is only one cited Capability Gap Statement in the GRMP for this focus area (Table 6), it is that a HFSE would offer advantages over traditional simulation platforms for modeling contaminant transport. Thus, this area was chosen for Use Case development (Table 7). The UGV mission in this Use Case could be performed by autonomous, semi-autonomous or teleoperated UGV using both current and future vehicle platforms. It also supports homeland defense initiatives.

Table 6. Force Operating Capabilities (FOC) Capability Gap Statements identifying detect CBRN and toxic industrial agent/hazard releases.

FOC Area / Specific FOC	FOC Description	Abbreviated Capability Gap Statement
Protection FOC-07-01 Protect personnel	The elements of personnel are: medical, anti-terrorism, personal safety, fratricide, counter-drug, non-combatant evacuation, defensive deception and psychological operations, personnel recovery, consequence management, CBRN detection, CBRN protection, counterintelligence, human intelligence, explosive ordnance demolition, and maritime interdiction operations.	3.7.3 Ability to detect and warn Soldiers of CBRN and toxic industrial agent/ hazards releases, Ability to provide mass casualty decontamination, and detect CBRN-loaded IEDs.

Table 7. Use Case for responding to a CBRN attack.

Use Case #3: Respond to CBRN Attack	
Name Description	Respond to CBRN Attack.
Situation	A unit is attacked by a road-side IED containing a persistent

	agent. Possibility of enemy fire.
Task	Respond to CBRN attack using UGV in supporting effort.
Purpose	Secure area, conduct stand-off detection, conduct sampling.
Doctrine	ART 2.3 Conduct Intelligence, Surveillance, and Reconnaissance ART 2.3.3 Conduct Tactical Reconnaissance ART 2.3.4 Conduct Surveillance ART 6.9 Conduct CBRN Operations ART 6.9.4 Provide CBRN Passive Defense MCT 2.2 Collect Data and Intelligence MCT 2.2.1 Conduct Tactical Reconnaissance MCT 2.2.9 Conduct Reconnaissance and Surveillance MCT 6.4 Operate in a CBRNE Environment MCT 6.4.3 Conduct Chemical, Biological, Radiological, and Toxic Industrial Chemical Agent Detection, Identification, Monitoring, and Sampling Operations MCT 6.4.5 Conduct Enhanced Nuclear, Biological, and Chemical (NBC) Operations
Notes	This Use Case will demonstrate using a robotic platform in limited access areas for chemical and radiological detection. It may contain but is not limited to a chemical and biological air and surface collection.

4.1.4. Use Case #4: Reconnaissance and Surveillance of a Building

Use Case #4 is a combination of the maneuver, search, detect, and locate and provide surveillance tasks (Table 2 and Table 4). It extends the previous Use Cases by including the need to enter the building as part of the reconnaissance. This scenario could incorporate multiple UGVs, UAVs, and fixed sensors in autonomous, semi-autonomous, or teleoperated fashion. It is applicable to current and future platforms. The scenario is documented in Table 8.

Table 8. Use Case for providing reconnaissance and surveillance of a building.

Use Case #4: Conduct Reconnaissance and Surveillance of a Building	
Name Description	Reconnaissance and surveillance of a building
Situation	A building is suspected of being an IED factory. Building has people in it – maybe mix of insurgents and local nationals.
Task	Conduct reconnaissance and surveillance.

Purpose	Provide information about the activities and resources of the enemy. Provide surveillance of building until friendly forces secure it.
Doctrine	ART 2.3 Conduct Intelligence, Surveillance, and Reconnaissance ART 2.3.3 Conduct Tactical Reconnaissance ART 2.3.4 Conduct Surveillance MCT 2.2 Collect Data and Intelligence MCT 2.2.1 Conduct Tactical Reconnaissance MCT 2.2.9 Conduct Reconnaissance and Surveillance
Notes	

Chapter 5: Summary

The stakeholder analysis completed was instrumental in identifying the Capability Gaps that helped derive these four Use Cases. These Use Cases represent areas of concern within the defense community and will be beneficial in the testing of UGVs in the HFSE. The problem of modeling and assessing UGV navigation, maneuver and mobility is sensitive to content, fidelity and resolution of the synthetic environment. There is a need for HFSE that developers, analysts and other stakeholders can use for modeling and assessments. The objectives are to develop a framework for assessing design alternatives for HFSE architecture and to cultivate HFSE development through experiments linked to missions and capabilities of UGVs. The Use Cases developed here will provide the structure in which we can analyze both the HFSE and the UGV performance in the HFSE.

Chapter 6: Future Work

We are currently developing a physics-based, multi-scaled numerical testbed that provides an enriched virtual environment for local sensor evaluations and fusion of global and local mobility-critical environmental factors and Joint Architecture for Unmanned Systems (JAUS) compliant virtual testing of UMS for intelligent autonomous navigation and tactical behaviors. A series of experiments will be developed which will leverage the functionality of

these Use Cases. Experiment 2 will demonstrate a high fidelity UGV model interacting with a lower resolution operational driver while utilizing Use Case #1. Follow-on experiments will exercise the other Use Cases while expanding upon the functionality of the UGV testbed. We expect that further Use Cases of this nature will be developed as the HFSE is developed and as the community sees the potential of UGV assessment in these environments as a result of experimentation within the geospatially enriched environments via HFSE. Each successive experiment is an evolution that will facilitate insights into the HFSE as it pertains to UGV assessment.

References

- Bruemmer, D.J., C.W. Nielsen, and D.I. Gertman. 2008. *How training and experience affect the benefits of autonomy in a dirty-bomb experiment*. In Proceedings of the 3rd ACM/IEEE International Conference on Human Robot Interaction, 12-15 March, 2008, Amsterdam, Netherlands.
- Defense Acquisition University. 2007. *Army Aviation Technology Assessment and Transition Management (TATM) Process Guide*. Department of Defense, Defense Acquisition University. February 2007.
- Goerger, N.C., V.D. Moore, and J.A. Nagle. 2008. *Investigation of Stakeholder Needs Regarding a High-Fidelity Synthetic Environment for Developing and Assessing Unmanned Ground Vehicle Systems and Subsystems Performance*. U.S. Army Engineer Research and Development Center, Geotechnical and Structures Laboratory. Report No.: ERDC/GSL TR-08-xx.
- Headquarters Department of the Army. 2003. *The Stryker Brigade Combat Team Infantry Battalion, Field Manual 3-21.21*. 8 April 2003.
- Headquarters, Department of Army. 2007. *The Army Universal Task List*, Field Manual 7-15. Final Draft 14 Nov 2007.
- Headquarters, Department of Navy. 2007. *Universal Naval Task List (UNTL), Version 3.0*. OPNAVINST 3500.38B/MCO3500.26A/USCG COMDTINST 3500.1B. 30 January 2007.
- Joint Ground Robotics Enterprise. 2006. *Report to Congress: Development and Utilization of Robotics and Unmanned Ground Vehicles*. Office of the Under Secretary of Defense, Acquisition, Technology and Logistics, Portfolio Systems Acquisition, Land Warfare and Munitions, Joint Ground Robotics Enterprise (JGRE).
- Nielsen, C.W., D.I. Gertman, D.J. Bruemmer, R.S. Hartley, and M.C. Walton. 2008. *Evaluating robot technologies as tools to explore radiological and other hazardous environments*. 12th Topical Meeting on Robotics and Remote Systems for Hazardous Environments, 5-12 March, 2008, Albuquerque, NM.
- Office of Secretary of Defense. 2007. *Unmanned Systems Roadmap (2007-2032)*. December 2007.
- Robotic Systems Joint Project Office. 2007. *Army/Marine Corps Ground Robotics Master Plan, Version 3*. Office of the Program Executive Officer Ground Combat Systems Program Manager Robotic Systems Joint Project Office (RS JPO). 25 July 2007.

Appendix A: Acronyms

A	
ACM	Association for Computing Machinery
AT\AP	Antitank\Antipersonnel
ART	Army Tactical Tasks
AUTL	Army Universal Task List
B	
BLOS	Beyond Line of Sight
C	
CBRN	Chemical, Biological, Radiological, and Nuclear
CBRNE	Chemical, Biological, Radiological, Nuclear, and High-Yield Explosive
CG	Commanding General
D	
DoD	Department of Defense
E	
ERDC	U.S. Army Engineer Research and Development Center
F	
FOC	Force Operating Capabilities
G	
GRMP	Ground Robotics Master Plan
H	
HFSE	High-Fidelity Synthetic Environment
I	
IEEE	Institute of Electrical and Electronics Engineers
IED	Improvised Explosive Device
J	
JAUS	Joint Architecture for Unmanned Systems
JGRE	Joint Ground Robotics Enterprise
L	
LOS	Line of Sight
M	
MANSCEN	Maneuver Support Center
MARCORSYSCOM	Marine Corps Systems Command
MCT	Marine Corps Tasks
MCTL	Marine Corps Task List
MEVA	Mission Essential Vulnerable Area
MOUT	Military Operations in Urban Terrain
N	
NLOS	Non-line of Sight
O	
ORCEN	Operations Research Center of Excellence
OSD	Office of the Secretary of Defense
P	

PEO-GCS	U.S. Army Program Executive Office Ground Command Systems
R	
RDECOM	Research, Development, and Engineering Command
RS JPO	Robotic Systems Joint Project Office
S	
S&T	Science and Technology
SDP	Systems Decision Process
SSTRO	Stability, Security, Transition, and Reconnaissance Operations
T	
TATM	Technology Assessment and Transition Management
TRADOC	U.S. Army Training and Doctrine Command
U	
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
UMS	Unmanned Systems
UNTL	Universal Naval Task List
USMA	United States Military Academy

Distribution List

NAME/AGENCY	ADDRESS	COPIES
Author(s)	ATTN: Joyce A. Nagle, Ph.D. US Army Engineer Research and Development - Center Cold Regions Research and Engineering Laboratory 72 Lyme Road Hanover, NH 03755	1
	ATTN: Niki C. Goerger, Ph.D. ATTN: LTC Suzanne DeLong U.S. Military Academy Department of Systems Engineering Mahan Hall West Point, NY 10996	2
Director, Joint Ground Robotics Enterprise (JGRE)	ATTN: Director, JGRE OUSD(AT&L)/PSA, LW&M 3090 Defense Pentagon Room 5C756 Washington, DC 20301-3090	1
PM, Robotic Systems Joint Project Office	ATTN: PM, RS JPO Building 3221 Snooper Rd Redstone Arsenal, AL 35898	1
Dean, USMA	Office of the Dean U.S. Military Academy Building 600 West Point, NY 10996	1
Director, ERDC	ATTN: Director U.S. Army Engineer Research and Development Center (ERDC) 3909 Halls Ferry Road Vicksburg, MS 39180-6199	1

NAME/AGENCY	ADDRESS	COPIES
Director, ERDC-CRREL	ATTN: Director US Army Engineer Research and Development Center - Cold Regions Research and Engineering Laboratory 72 Lyme Road Hanover, NH 03755	1
Defense Technical Information Center (DTIC)	ATTN: DTIC-O Defense Technical Information Center 8725 John J. Kingman Rd, Suite 0944 Fort Belvoir, VA 22060-6218	1
Department Head-DSE	U.S. Military Academy Department of Systems Engineering Mahan Hall West Point, NY 10996	1
ORCEN	U.S. Military Academy Department of Systems Engineering Mahan Hall West Point, NY 10996	5
ORCEN Director	U.S. Military Academy Department of Systems Engineering Mahan Hall West Point, NY 10996	1
USMA Library	U.S. Military Academy Library - Bldg 757 West Point, NY 10996	1
ERDC Library	ATTN: Head Librarian U.S. Army Engineer Research and Development Center (ERDC) 3909 Halls Ferry Road Vicksburg, MS 39180-6199	1
ERDC-CRREL Library	ATTN: Head Librarian US Army Engineer Research and Development Center - Cold Regions Research and Engineering Laboratory 72 Lyme Road Hanover, NH 03755	1

Chapter 7: REPORT DOCUMENTATION PAGE – SF298			<i>Form Approved</i> OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.				
1. REPORT DATE (DD-MM-YYYY) 30-09-2008		2. REPORT TYPE Technical Report		3. DATES COVERED (From - To) 1 Oct 07 - 31 May 08
4. TITLE AND SUBTITLE Initial Set of Use Cases for High-Fidelity Synthetic Environment/Virtual Autonomous Navigation Environment Development Tied to Unmanned Ground Vehicle Capability Gaps			5a. CONTRACT NUMBER	
			5b. GRANT NUMBER	
			5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Dr. Joyce A. Nagle Dr. Niki C. Goerger LTC Suzanne M. DeLong			5d. PROJECT NUMBER DSE-TR-0912	
			5e. TASK NUMBER	
			5f. WORK UNIT NUMBER (845) 938-3573	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Operations Research Center Department of Systems Engineering US Military Academy West Point, NY 10996			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) ERDC 3909 Halls Ferry Road Vicksburg, MS 39180-6199			10. SPONSOR/MONITOR'S ACRONYM(S)	
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Distribution A: Approved for public release; distribution is unlimited.				
13. SUPPLEMENTARY NOTES				
14. ABSTRACT To help guide alternative assessments and experiments for the development of a high-fidelity synthetic environment (HFSE), an initial set of Use Cases was developed based on Capability Gaps identified in the U.S. Army/U.S. Marine Corps Ground Robotics Master Plan (Robotics Systems Joint Project Office (RS JPO), 2007). Four specific scenarios were developed in which an unmanned ground vehicle (UGV) is employed to contribute to a mission. The Use Cases are narrative descriptions of a sequence of actions a Warfighter equipped with a UGV, would undertake to accomplish a goal. The Use Cases do not identify requirements, but rather imply them in the stories they tell, leaving it up to an analyst to identify the requirements. The Use Cases avoid identifying or describing specific platforms, but rather create opportunities for analysts to identify capabilities. The Use Cases developed will provide the structure in which we can analyze both the HFSE and the UGV performance in the HFSE.				
15. SUBJECT TERMS High-Fidelity Synthetic Environment, use cases, unmanned ground vehicle capability gaps				
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT None	18. NUMBER OF PAGES 25
a. REPORT	b. ABSTRACT	c. THIS PAGE		
				19a. NAME OF RESPONSIBLE PERSON LTC Suzanne M. DeLong
				19b. TELEPHONE NUMBER (include area code) (845) 938-3573